BCI ASSIGNMENT - 1

Indian Institute of Information Technology, Sri City.

Brain Computer Interaction

Report:

ARM AND HAND MOVEMENTS DECODED FROM PERSONS WITH SPINAL CORD INJURY

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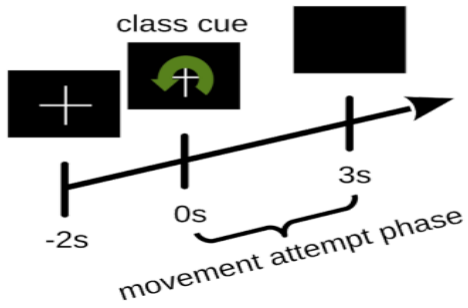
➢ **INTRODUCTION**:

- The persons with spinal cord injury (SCI) retain decodable neural correlates of attempted arm and hand movements.
- However, we observe that discriminative movement information was provided by time-domain of low-frequency electroencephalography (EEG) signals.
- Thus, a BCI device can detect these user induced changes in brain-signals and transform them into control signals for neuroprostheses or robotic arms

➢ DATASET DESCRIPTION:

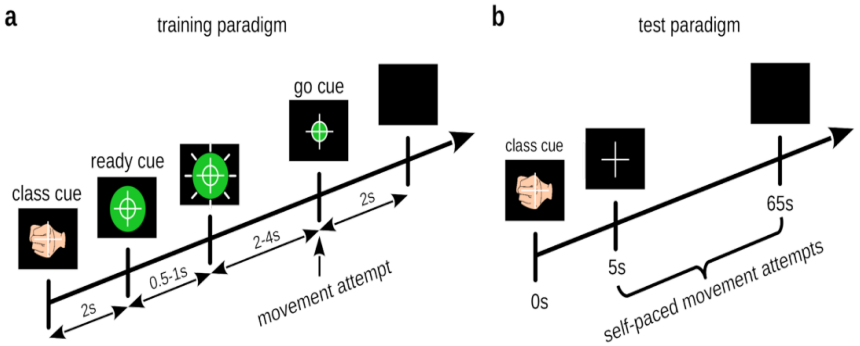
Offline Paradigm:

The data set comprises 15 runs per participant: 9 attempted movement runs, 3 eye movement runs, and 3 rest runs. Every run is stored in a separate GDF file.



Online Paradigm:

The data set contains GDF files for two online sessions. The first online session includes 9 training runs and 6 test runs; the second online session also includes 9 training runs but 5 test runs.



➢ LITERATURE REVIEW:

AUTHOR AND YEAR	TITLE	METHODOLOGY	EVALUATION PARAMETERS	DRAWBACKS
Ofner, P., Schwarz, A., Pereira, J., Wyss, D., Wildburger, R., & Müller-Putz, G. R. (2019) - Scientific reports, 9(1), 1-15.	Attempted arm and hand movements can be decoded from low-frequency EEG from persons with spinal cord injury. [2]	1. Movement classification. - Paradigm - Recording - Preprocessing - Classification 2. Proof-of-concept of an online classifier. - Paradigm. - Detection thresholds. - Defining the true-positive window	True positives (TP): Predicted positive and are actually positive. False positives (FP): Predicted positive and are actually negative. True negatives (TN): Predicted negative and are actually negative. False negatives (FN): Predicted negative and are actually positive. Confusion Matrix = [TP FN FP TN]	1. Improve the classifier's generalization capabilities as MRCPs depend on various factors, like force, speed, goal-directedness and attention diversion.

➢ EXPERIMENTAL SETUP:

- Users performed cue-guided setup. There were shown one of the 5 cue classes: pronation, supination, palmar grasp, lateral grasp or hand open.

- Users were asked to focus their gaze on the cross which was displayed during the whole trial period of 5s and then the class cue was displayed 2s after the trial start for 3s.

- After the trial, a break with a random duration of 1s to 3s followed.

- Total of 9 runs with 40 trials per run, i.e. 72 trials per class in total were recorded.

- Total of 10 users participated in this experiment with ages from 20-69.

➢ **FEATURE EXTRACTION:**

Feature extraction refers to the process of transforming raw data into numerical features that can be processed while preserving the information in the original data set. It yields better results than applying machine learning directly to the raw data.

1. **FFT of the data**

FFT is computation of Discrete Fourier transform in an algorithmic format, where the computational part will be reduced. Extracting features from time series data is challenging.

$$x[K] = \sum_{n=0}^{N-1} x[n] W_N^{nk}$$

It is important to convert our data which is in time series format into frequency format, so we can extract the frequency related data from it.

For this we have performed FFT using Numpy FFT library. We get all the data in complex form. We also calculate the corresponding frequency range according to the time series using the Numpy fft.fftfreq method.

2. Logarithmic Power bands

We have calculated the logarithmic power bands of the data. We have added this transformation to every column of our data.

Hence, the number of features of our next step are 6 (as described in the paper). Those are:

1. Logarithmic power band of Alpha - C3.
2. Logarithmic power band of Alpha - C4.
3. Logarithmic power band of Alpha - Cz.
4. Logarithmic power band of Beta - C3.
5. Logarithmic power band of Beta - C4.
6. Logarithmic power band of Beta - Cz.

3. Relevant feature extraction and selection

For feature extraction we have taken the features from C3, C4 and Cz. After taking these features we have extracted the following band of frequencies of the data:

a. Alpha band (10 - 13 Hz)
b. Beta band (16 - 24 Hz)

Alpha Waves : Alpha waves are one type of brain waves detected by electrophysiological and closely related methods, such as by electroencephalography (EEG) or magnetoencephalography (MEG), and can be quantified using quantitative electroencephalography (qEEG).

Beta Waves : Beta brain waves (16 – 24 Hz) are small, faster brain waves associated with a state of mental, intellectual activity and outwardly focused concentration. This is basically a state of alertness.

4. Fisher score:

Fisher score is one of the most widely used supervised feature selection methods.

However, it selects each feature independently according to their scores under the Fisher criterion, which leads to a suboptimal subset of features. Fisher Score is computed as :

$$F(\mathbf{Z}) = \mathrm{tr}\left\{(\tilde{\mathbf{S}}_b)(\tilde{\mathbf{S}}_t + \gamma\mathbf{I})^{-1}\right\}$$

$$\tilde{\mathbf{S}}_b = \sum_{k=1}^{c} n_k(\tilde{\boldsymbol{\mu}}_k - \tilde{\boldsymbol{\mu}})(\tilde{\boldsymbol{\mu}}_k - \tilde{\boldsymbol{\mu}})^T$$

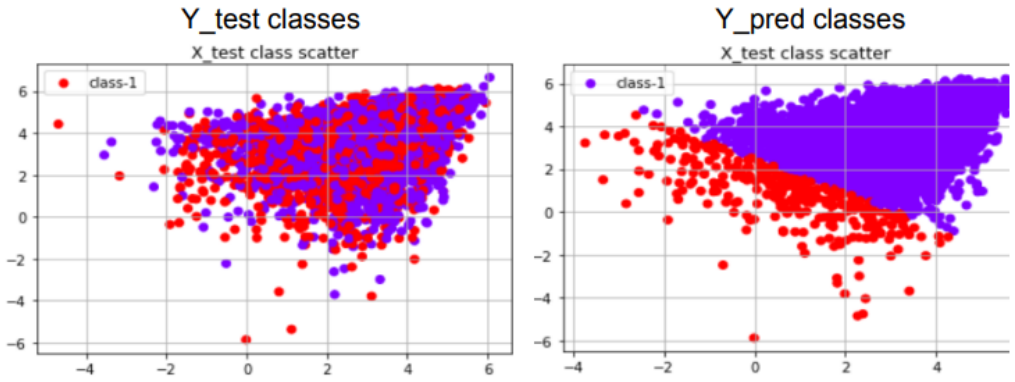
$$\tilde{\mathbf{S}}_t = \sum_{i=1}^{n}(\mathbf{z}_i - \tilde{\boldsymbol{\mu}})(\mathbf{z}_i - \tilde{\boldsymbol{\mu}})^T,$$

➢ **<u>CLASSIFICATION ALGORITHM:</u>**

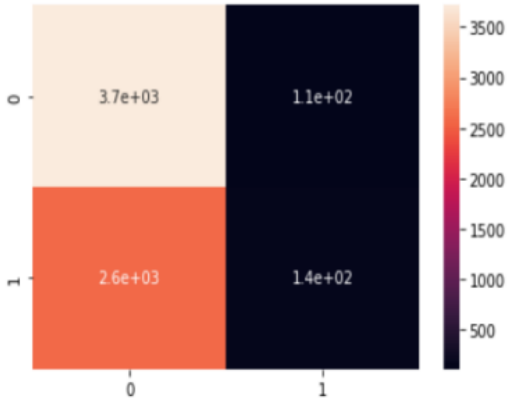
sLDA classifier:
➔Shrinkage linear discriminant analysis (sLDA) .
➔Input to the sLDA classifier were the EEG samples from all low noise channels.
➔EEG samples spaced in 200ms intervals were taken from a time window, i.e. the feature extraction window, and fed into the classifier.

➔The output of the classifier was normalised with a softmax function to obtain probabilities.

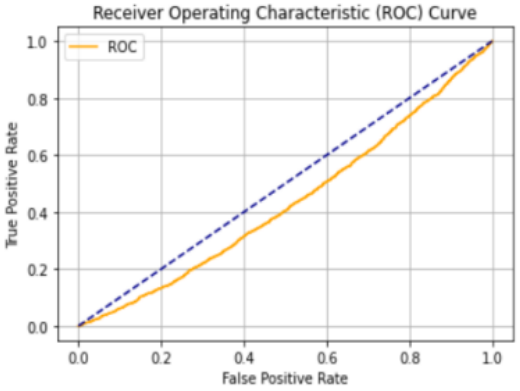
The graph comparisons are as follows :



Confusion matrix:



ROC curve



➢ RESULTS:

1) Movement Classification:

● This was done with a shrinkage linear discriminant analysis (sLDA) classifier.

● It yielded a grand average accuracy, which peaked with 45.3% at 1.1 s after class cue presentation as shown in the figure.

●The confidence interval at this peak was found out to be [40.3%, 50.3%].

2) Proof-of-Concept classifier:

- The feature extraction window was shifted along the trial in steps of 1/16th of a second, and calculated classification accuracies were validated with a trial-based 10×10 cross-fold validation.

- It shows a modest classification performance of 68.4% with respect to palmar grasp vs hand open classes.

➢ **REFERENCES:**

[1] BCI Horizon | (001-2019) Dataset Description PDF. Link

[2] Ofner, P., Schwarz, A., Pereira, J., Wyss, D., Wildburger, R., & Müller-Putz, G. R. (2019). Attempted arm and hand movements can be decoded from low-frequency EEG from persons with spinal cord injury. Scientific reports, 9(1), 1-15. Link

[3] Attempted arm and hand movements in persons with spinal cord injury (001-2019) | BCI Horizon | Dataset. Link